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ENGLISH AIRPLANE CONSTRUCTION

By D. Schwencke

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

TECHNICAL MEMORANDUM NO. 595

ENGLISH AIRPLANE CONSTRUCTION*

By D. Schwencke

At the end of the war the dependence on foreign markets had almost wiped out quantity production of wooden airplanes in England, but even at that time a tendency had developed to manufacture at least some parts of other materials, particularly steel. As a result, the transition was gradual and systematic without radical departures in shapes or types, in contrast to the German development of metal airplane design where, building under new, theoretical, aerodynamic considerations, it led to complete breaking away from all conventional practice.

The English steel industry with its wealth of experience back of it, encouraged those tendencies and supplied the airplane industry with the necessary thin-gauge steel strip. Thus, the reconstruction of its conventional airplane types with their particular aerodynamic characteristics, remained the guide of the English metal airplane manufacturer.

Steel Ribs and Fabric Covering

Steel construction is particularly suitable for speedy, maneuverable biplanes, but not for multi-engined airplanes or cantilever monoplanes.

*"Konstruktive und fabrikationstechnische Fragen des englischen Flugzeugbaues." From V.D.I. (Zeitschrift des Vereines deutscher Ingenieure, August 2, 1930, pp. 1085-1090.)

Grimly adhering to the old standards of construction - braced biplanes with flat wing section, constant spar height and low landing speed, at times even resorting to wing slots - the steel strip and light metal construction have nevertheless evolved some very ingenious types of structural members, which were adopted both for military and commercial airplanes.

The principal advocates of pure steel construction with fabric covering are: Armstrong and Whitworth, Boulton and Paul (builders of the R 101), and The Bristol Aeroplane Co. Other firms using light metal are: Handley Page, Blackburn, De Havilland, Gloster, and Hawker; while Vickers, Short and Supermarine use duralumin almost exclusively.

The English steel aircraft construction is based on steel strip for high-tensile nickel-chrome steel, shaped by drawing and rolling to insure the desired strength in buckling and bending. In this each firm gained its own particular experience, which resulted in a series of proven spar sections and shapes (Figs. 1-12).

The cheapest and simplest section, from the shop viewpoint, is the closed section (Fig. 1), furnished as annealed, cold-drawn seamless steel tubing to the Fairey and Hawker companies. One disadvantage of this type of spar section is that the spar is stressed as a pure beam in bending, that is, principally in the flanges. After riveting the stiffening plate, the fittings are simply bolted together (Fig. 1).

Figures 2-12 represent some more complicated spar sections, consisting of drawn or rolled sections. Here the steel strips are from 0.13-0.8 mm thick, and have a tensile strength of from 80-120 kg/mm². The accuracy in manufacture is contingent upon the strip thickness and averages about +0.01 mm for the 0.2 mm thickness, and +0.02 mm for the 0.4 mm plate. Another fact worth mentioning is that the fine gauge nickel-chrome sheet steel is still imported from Sweden, England not having overcome as yet certain difficulties in the rolling process.

In the Hawker type spar (Fig. 2), the top and bottom flanges and the web are separately rolled strips riveted together. The rolling begins at the edge of the strip and is continued in two rolls for each new bend. Hawker cold-rolls the already tempered sheets without further heat treatments. The disadvantage of this method lies in the possible strength changes due to the marked local bending of the strip when cold-rolled, and which makes it impossible to use hardened high-tensile steel, because it is too stiff to roll. The difficulty of producing closed sections in rolls, consists in the working of the final pair because the gap, contingent upon the width of the rolls, becomes larger, depending on the amount of spring-back of the metal strip. The open flange section is then pressed together and solidly riveted to the web.

The spar section of the Armstrong and Whitworth firm (Figs. 3-5) is similar to Hawker's, but the flanges are divided into

three equal round ones. They are drawn in the softened, annealed state and then electrically hardened. Then the cooled sections are filled with carbonic acid and brought to the desired annealing temperature by means of a 30-volt (600-800 watt) current, cooled by compressed air and put in the oil bath. This method is expensive, but it takes full advantage of the high-tensile strength properties of the material.

The three individual channel sections are equipped with flanges, so that clamping sleeves can be fitted over them which, combined with the riveted flange parts, hold the assembly together. The chief object of the sleeves is to tack the flange pieces together for the semiautomatic method of riveting. Hollow rivets are used on account of their low crushing pressure.

The Boulton and Paul, and the Bristol type spars (Figs. 6 & 7) are much more complicated - have a higher distortion stiffness and show a very simple rib attachment. For the rest, the spar sections are much divided, the individual strips having fitted pleats or curls, so that they can be riveted semiautomatically. The method is similar to that of Armstrong and Whitworth, except that all working processes are combined into one continuous procedure. Before drawing the steel strip passes through an electric furnace. When bright red, it passes through the individual water-cooled drawplate or die, after which it is cool enough to undergo the electrical hardening process. In the

Supermarine spar (Fig. 8), the transition from wooden construction becomes readily apparent; it consists of two U-section flanges and separate U-section webs. This method of construction is very expensive and will eventually be superseded by solid-drawn tubing or drawn or rolled sections. The lengthwise corrugated webs, moreover, do not need any vertical stiffening, because the ribs, fastened at the sides, already act as such.

The practical application of the above spar sections hinges primarily on their fitness for attaching the rib, strut and bracing wire fittings, the inside spacers mounted between front and rear spar, and the internal wing bracing. This is particularly difficult with closed spar and flange sections. Before it could be used, special hollow rivet methods had to be developed. Thus, in the Hawker and Fairey spar an exact fitting tube is riveted first at one panel point, which offers sufficient hold for the fittings bolted on the outside.

The hollow rivet *a*, is fastened with a steel pin *b*, having a hardened conical head *c*, which fits into the rivet (Fig. 9). The head has the same diameter as the rivet shank, so that both can be inserted together. The riveting tongs *G*, are placed against the rivet head and the steel pin forced outward; then the inside part of the hollow rivet is crimped until the pin shears off on the shank or on the head. With this method it is very important that the rivet body have the exact length. It is used only for transmitting pure shearing stresses,

and is unsuitable for even low-tension stresses.

A somewhat more complicated joint is seen in Figure 3, which is from the Armstrong-Whitworth firm. Here the web is first stiffened by two side plates which, by means of special interlayers, fit snugly to the sides of the spar flanges. They are, surprisingly, bolted - not riveted - on. Top and bottom flanges are stiffened on the inside by short insertion tubes. The fittings themselves are fitted to the flange sections. The ribs are attached as shown on Figure 5; they are supported on top and bottom flange by small blocks, or else pressed by special apparatus against the curl of the spar flanges. On the leading edge of the ribs is a small curled edge for the sleeve which extends over the whole span, giving the leading edge a solid shape.

For protection against lateral slippage, small strips are used in the rib sleeve, which are slipped over the curled edge and crimped or clipped in place. Since there is no solid connection between ribs and spars, every wing has at least two stronger main ribs which are bolted to the spar. In the junction on Figure 7, the sides are similarly stiffened by the spars, after which the whole fitting is attached.

In Figure 10, we see the wing structure of a Fairey biplane, which illustrates the changing-over particularly well. All parts of the wooden structure, such as front and rear spars, ribs and false ribs, leading edge strip (here a simple duralumin tube), spacing tubes, and internal bracing are of strip steel or dural-

umin. Figure 11 shows a very simple rib attachment to the spar, as practiced by the Bristol firm. The ribs are slipped over the spar, and secured by means of the fittings a. In Figure 12, we see two ordinary steel fittings of the Supermarine company for attaching a number of rustproof connections at one point.

Fuselage Construction

Here the use of steel and fabric covering is more common than in the wing construction, with the exception of the flying boats which are, of course, of light metal. The first principle again is: use of materials of high-tensile strength, which accounts for the absence of welding in continuous beams (Fig. 13). Other considerations are, facility of disassembly - at least, complete and quick separation of front, middle, and end of fuselage. Several firms, such as the Handley Page, go so far (in the "Moth" type) as to use bolts for the fuselage assembly. Aside from the interchangeability, this feature makes it particularly suitable for colonial shipment.

In fuselage construction there are two main groups, one using high-tensile, seamless, drawn tubes with welding in the auxiliary members (Figs. 13-25) (represented by Hawker, Blackburn, Gloster, Fairey, Vickers, De Havilland, Handley Page, and others); and the other group using high-tensile, thin, solid-drawn, nickel-chrome steel tube, with special fittings, such as

used in the R 101 (representing Armstrong and Whitworth) (Fig. 26), Boulton and Paul, and Bristol). Figure 18, in particular, shows the end fitting to the square-section tubing, while Figure 19 depicts a hinged fitting. In Figures 20-21, which represent a detachable steel junction, a is the tubular spar, b the tubular webs, c the fitting, d the bolt for the internal bracing, and e the pin joint. Figure 22 shows an S-shaped stiffener in a square-section tube, Figure 23 a wing-panel point, and Figures 24 and 25 a floor carrier and its attachment to the spar.

Welding is, of course, excluded with such material. Even solid-drawn tubing is welded only in flat pieces. Recently, the Handley Page company developed junction points on continuous spars by welding a small block on it to which the webs and diagonals are then welded. In this manner the annealing confines the disturbance in the strength characteristics of the main spar to a very small space.

As Figures 14-25 show, solid-drawn tubes are quite often used as square-section profiles, for ensuring better joints with simple, flat junction plates.

Light Metal - Particularly Duralumin Construction

Lacking sufficient raw materials for unlimited construction in light metals, it is not surprising that light metal construction has not made any more progress. One notable exception

is the Vickers company. Thus, we see in Figure 27 one of their duralumin spars comprising two U-section flanges and a vertically corrugated web. Figure 28 represents a Supermarine spar, similar U-section flanges with one corrugation plate, to which the rustproof fitting is attached. Figure 29 shows the structure of the Handley Page wing, type Hinaidi, and Figure 30, a cross section of the spar.

Another notable type of spar is that of the Blackburn-Nile monoplane flying boat (Fig. 31). The spar is so high that it has to be built as lattice beam with inertia moment tapering toward the tips. This type of construction - semicantilever monoplane with great spar height tapering toward the tips - seems to be particularly suited to light-metal construction, while the use of nickel-chrome steel strip engenders many structural difficulties. The buckling strength of thin sections decreases materially as the height of the structure increases, particularly with larger flat sides; in addition, the advantage of quick manufacture by drawing or rolling is lost again, owing to the decreasing structural spar height for static and aerodynamic reasons.

The real field of steel strip construction is characterized by its particular suitability for absorbing high stresses by small dimensions, while light metals always insure a better utilization of material by larger dimensions. This is the reason England takes so reluctantly to the modern construction

principles of multi-engine airplanes. The light-metal hull construction of the English flying boats is similar to the German. Thus we see, for example, in Figure 32, the inside of the hull of the Supermarine-Southampton flying boat, with its carefully constructed, open bulkheads. The float construction of The Fairey Company also merits special notice.

Clean shopwork, high quality of materials, and their systematic heat and protective treatment leave the most profound impression on the visitor. The English aircraft industry lays special stress upon protection against atmospheric conditions and electrolytic phenomena. They advocate:

- a) The use of rustproof steel wherever feasible, particularly for steel fittings on duralumin;
- b) Anodic oxidation in cadmium or zinc bath, of all parts susceptible to corrosion;
- c) Spraying of all parts with a particularly adhesive varnish followed by a two- to four-hour drying in an oven from 200 to 300°C.

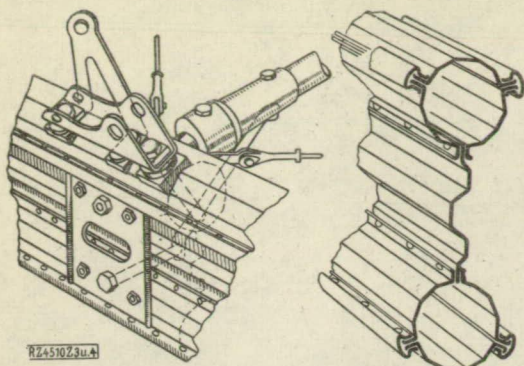
The main structural principles of the English aircraft industry may be summed up as follows:

- 1) Quick and easy assembly and disassembly, hence complete finishing of all components (quantity production);
- 2) Structurally simple attachments; avoidance of riveting and preference for easily detachable clamp and screw connections in contrast to Junkers, Rohrbach, and Dornier;

- 3) Accessibility of all components for inspection of rivets and screws;
- 4) Great care in selection of material properties for construction by close cooperation with raw material producers;
- 5) Increase in speed range by using automatic slots on wings, thus lowering landing speed and eliminating danger of spin.

It must be conceded that England has accomplished this to a great extent. Individually the English methods may serve as an example, particularly as to utilization and treatment of materials, although adoption of their structural methods on a larger scale does not seem practical.

Translation by J. Vanier,
National Advisory Committee
for Aeronautics.



Figs.3,4 Armstrong and Whitworth junction point and drawn steel spar.

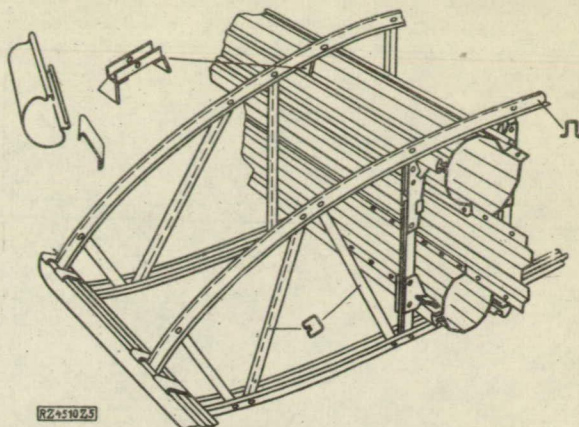
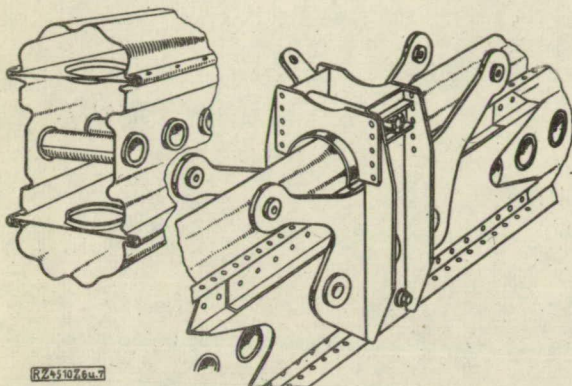


Fig.5 Armstrong and Whitworth rib attachments,



Figs.6,7 Boulton and Paul spar and junction point.

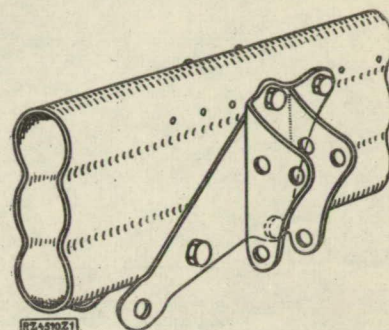


Fig.1 Hawker tubular steel spar

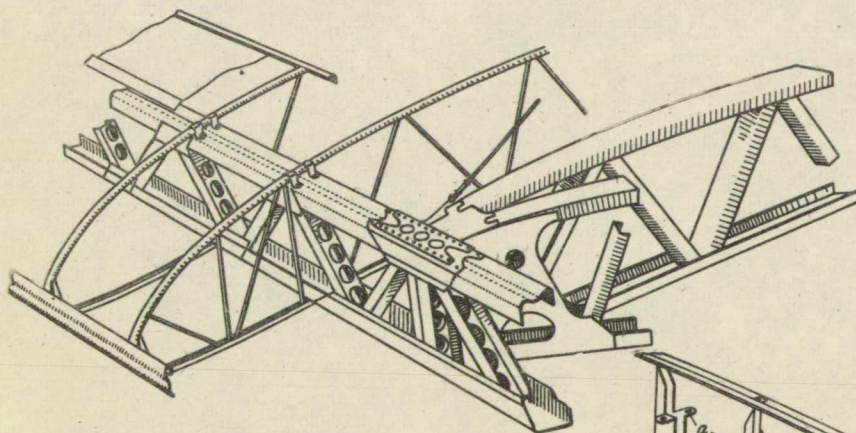


Fig.8 Supermarine wing spar and rib attachment.

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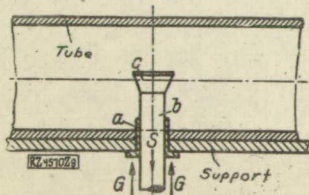


Fig.9 Method of riveting.

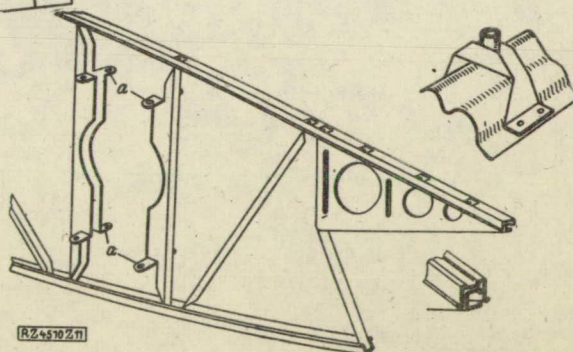


Fig.11 Bristol wing rib with fittings.

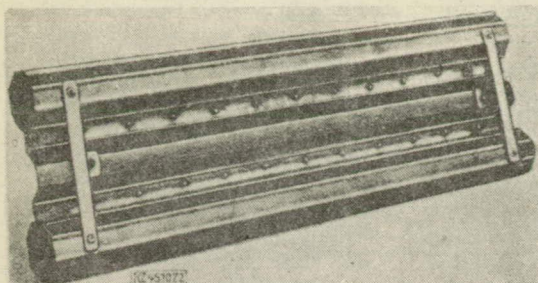


Fig. 2 Hawker rolled steel spar.

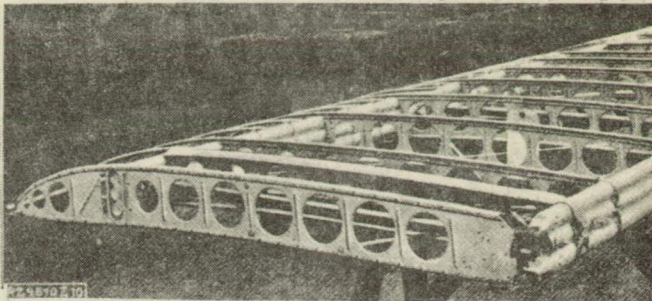


Fig. 10 Fairey wing structure.

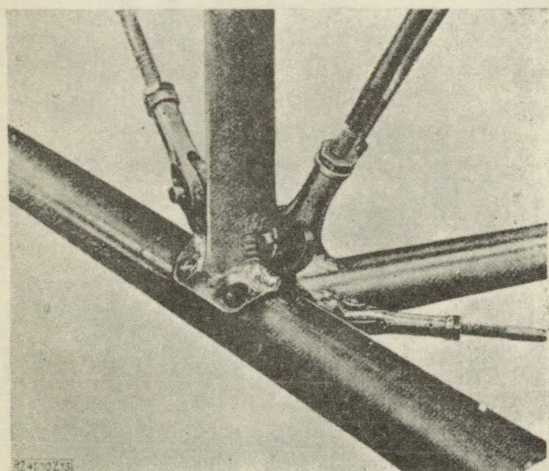


Fig. 13 Fairey fuselage longeron.

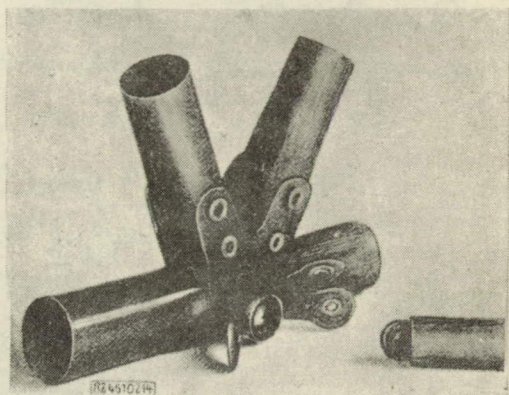


Fig. 14 Hawker fuselage junction.

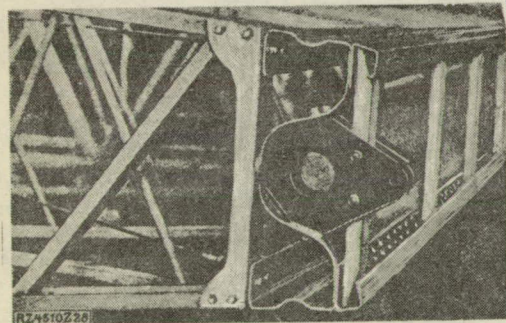


Fig. 28 Supermarine wing spar.

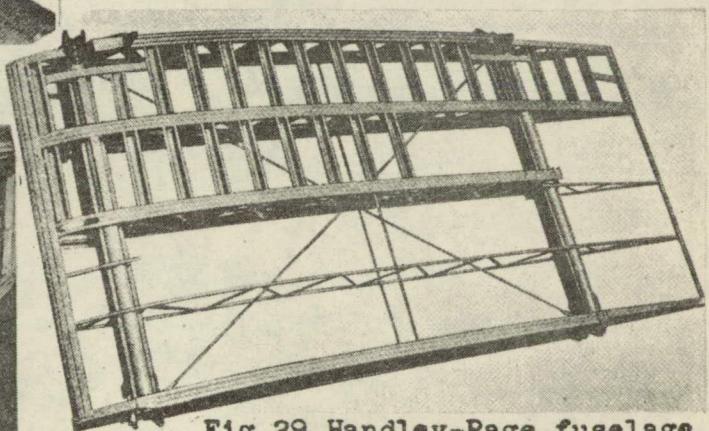


Fig. 29 Handley-Page fuselage fitting of lower wing.

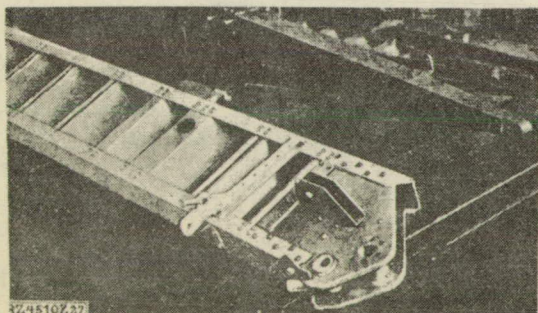


Fig. 27 Vickers duralumin wing spar.

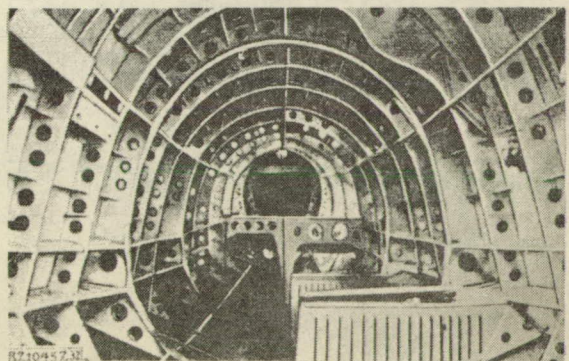


Fig. 32 Supermarine hull, inside view.

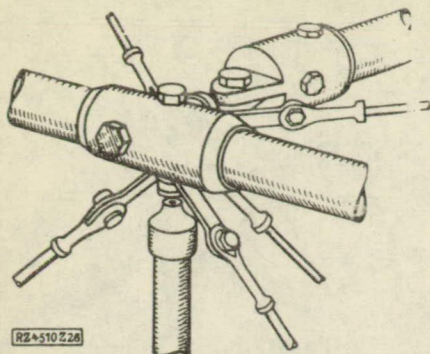


Fig.26 Armstrong fuselage junction point.

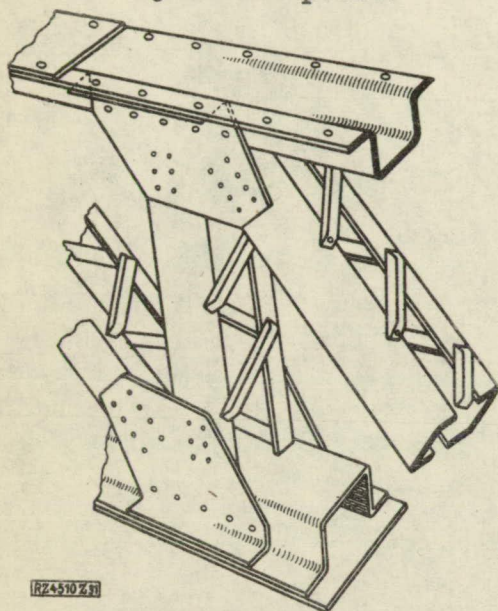


Fig.31 Blackburn duralumin wing spar.

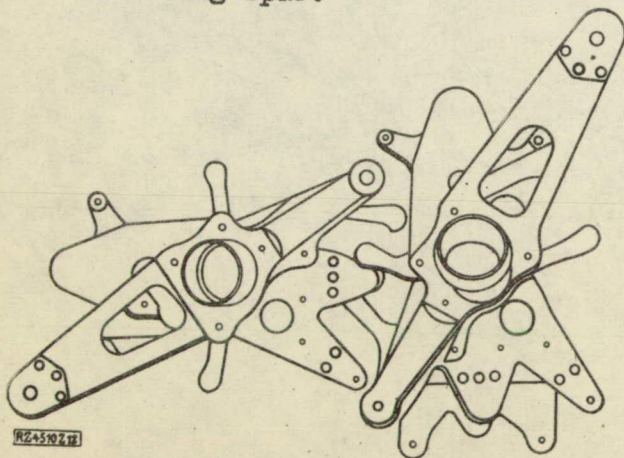
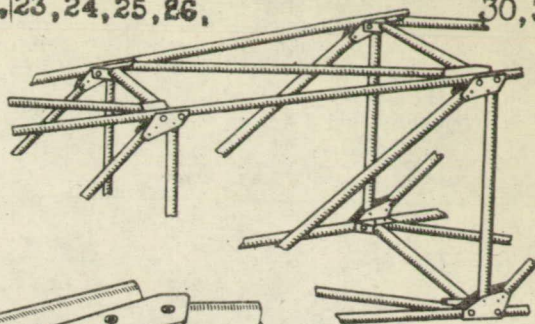


Fig.12 Supermarine rust proof fittings.



Figs.15,16,17 Blackburn steel tube fuselage.

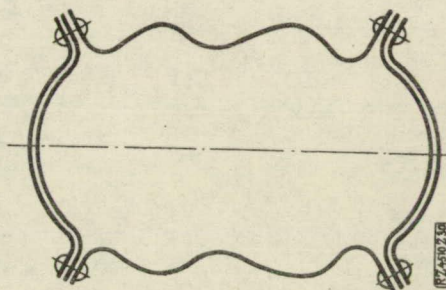
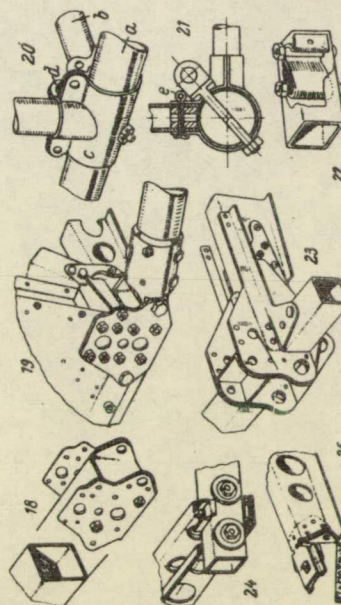


Fig.30 Handley-Page wing spar section.



Figs.18,19,20,21,22,23,24,25 Gloster fuselage junctions.